Directionally Drilled Bores For Remote Cable Landings

N.A. Sinclair, Naval Facilities Engineering Service Center, Port Hueneme, CA
H.G. Thomson, Naval Facilities Engineering Service Center, Port Hueneme, CA
S.A. Black, Sound & Sea Technology, Inc., Ventura, CA
R. Roberts, DitchWitch Northwest, Kennewick, WA

Naval Facilities Engineering Service Center
1100 23rd Ave.
Port Hueneme, CA 93043 USA
sinclairna@nfesc.navy.mil

Abstract - A cable shore landing protection system was needed at Southwest Bay, Ascension Island, to protect future cables coming ashore. Three subsurface conduits were installed from the shore out under the seafloor, using a lightweight horizontal drill rig. These three Directionally Drilled Boreholes range from 500 to 800 feet in length, and exit the seafloor at water depths of 35 feet or greater. These boreholes were installed in late August and early September of 2002. This effort took 13 days on site to accomplish.

INTRODUCTION

A cable shore landing protection system was needed at Southwest Bay (see Figure 1), Ascension Island, South Atlantic Ocean, to protect three future Hydroacoustic Data Acquisition System (HDAS) cables coming ashore. This system was needed to by-pass the sea-shore interface and high energy surf zone, which poses the greatest hazard to the survivability of cables at this facility.

Prior cables coming ashore at this site were stabilized with split-pipe, and trenched across a beach (through a turtle nesting ground). These cables suffered many failures in this nearshore region, as indicated in Figure 2.

Figure 1. Southwest Bay, Ascension Island.

Figure 2. Exposed Split Pipe.

A detailed survey of the nearshore seafloor was conducted. This was needed to identify a subsea cable route which would minimize any reef crossings in the approach to shore, to support concept development for the cable protection system, and then to identify the optimum location for the cable shore landing.

LIFE CYCLE COST ANALYSIS

A life cycle cost analysis was conducted to determine the most appropriate method of protecting the new cables coming ashore. This analysis compared the life cycle cost, complexity, and risks associated with the following two approaches.

Conventional Split Pipe: This method protects the cable by bolting lengths of heavy weight cast iron split pipe around the cable, and anchoring the pipe directly to the seafloor.

Directionally Drilled Bores (DDBs): This technique consists of drilling a horizontal hole from the beach out to a water depth beyond the high-energy wave zone. A liner is then pulled into the borehole, and the cable is later pulled through the liner to the beach anchor or vault.

This study concluded that the long term (20-year) cost of installing and maintaining a conventionally installed cable protection system was about 50%

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **01 SEP 2003**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**

4. TITLE AND SUBTITLE **Directionally Drilled Bores For Remote Cable Landings**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Facilities Engineering Service Center, Port Hueneme, CA**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM002146. Oceans 2003 MTS/IEEE Conference, held in San Diego, California on September 22-26, 2003. U.S. Government or Federal Purpose Rights License., The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**UU**	**5**	

greater than that of a directionally drilled borehole system. This estimate did not take into account the potential for weather delays during cable/split-pipe installation, or the environmental impact of trenching through an ecologically sensitive beach.

The ability to decouple the DDB operations from the cable installation operation significantly reduces the cost and schedule risks of the cable installation. The directional bores can be drilled at any time prior to the actual cable installation operations, and the time required to install the cables through DDBs is substantially less than with split pipe.

It should also be noted that the diver activities required for the DDB cable protection approach is minimal. For a conventional installation, extensive and potentially hazardous underwater work is typically required to place the split pipe on the cable and anchor it to the seafloor. Since a substantial amount of this work is done in the high-energy surf zone, the risks to the divers are significant.

DRILL SYSTEM

The seafloor survey identified a path at the southern end of the bay where lava-rock outcroppings extend offshore 300 to 400 feet (to 35-foot water depth), after which the seafloor is relatively flat. This site offered the least distance to reach suitable water depths. Given this, and the setback from the shoreline necessary for conducting drilling operations, a horizontal drill rig was selected with a nominal range of 1,000 feet.

Another factor in drill rig selection was the size and mobility of the drill rig. Limitations in cargo access to the island and the limited footprint area on-site within which to operate demanded a compact minimal weight system. A lightweight horizontal drill system was leased to install these cable landing boreholes. The primary component of this system was a 200-hp DitchWitch All Terrain directional drill rig (shown in Figures 3 and 4).

Figure 3. Mobile Drill Rig, Front View.

Figure 4. Mobile Drill Rig, Side View.

Overall, the system consisted of the DitchWitch All Terrain directional drill rig, 1,300 feet of drill pipe, three 6-inch drill bits, a wireless drill head tracking system, two 9-hp mud mixers, two 1,000-gallon mud holding tanks and a vacuum trailer. Three 1,000-foot lengths of 3.5-inch diameter HDPE tubing (spooled on large diameter reels) were selected for the bore liner.

The remoteness of Ascension Island required detailed planning to ensure that the needed equipment and supplies were minimized, and were brought along. A particular concern was minimizing the drill mud requirements in order to minimize water requirements, since the only fresh water on the Island was generated at a desalinization plant.

A significant factor in selecting this particular drill rig was its dual concentric drill pipe with internal drive shaft for rotating the directional drill bit. This configuration reduces the amount of drilling fluid (and water) required by an order of magnitude compared with mud-motor drill systems. Further, this system was specifically designed for drilling through hard rock, which would be typical of the lava flow formation to be drilled at Ascension Island.

The drill pipe and drill mud supplies were shipped to the island via a bi-monthly cargo ship. The high value drill equipment and all personnel transited to the island on a C-17 military cargo aircraft.

DIRECTIONAL DRILLING

The objective of this drilling effort was for each borehole to exit the seafloor in a relatively benign region, as previously identified from the survey, and generally along the planned cable route. In order to estimate drill mud requirements, the initial drill plan called for two 800 foot boreholes to be installed. A sufficient amount of drill pipe, mud additives, and conduit were brought to complete three 1,000-foot boreholes. Mobilization of equipment and setup of the drill site took 1 day. This effort first consisted of

transporting the drilling equipment and supplies to the drill site from the airport, using three flatbed trailers. These trailers carried the drill rig, two mud mixing systems, 10 racks of drill pipe, and the drill fluid additives. The vacuum trailer was towed to the site. A fourth trailer was used to transport miscellaneous boxes of other supplies. An all-terrain forklift was used on site to offload the equipment from the trailers, and a backhoe was used to dig the drill entry pit. The all-terrain forklift was used to change out the drill pipe racks on the drill rig, which weigh 3,300 pounds when fully loaded with 9 pipe sections.

The first step for drilling a borehole is to develop a desired profile for the borehole path to follow. Application software is used to develop such a profile, and to provide the steering directions to achieve it. To keep within this profile, the drill head is steered as directed, to maintain the planned borehole profile.

A key aspect of any drill system is the ability to track the directional drill head position, inclination, clockwise orientation, and depth while drilling. This is vital for achieving the desired borehole path, and to exit the ground at a given target position. Figure 5 shows the hand-held drill-tracking unit that receives the electro-magnetic signals from the beacon housed within the drill head, and displays the associated drilling information (and also relays this information to the drill rig).

A floating marker line was rigged from shore out along the planned bore route. This served as a visual aid for estimating range offshore (the floats were spaced at known intervals) during drilling operations, and provided a means of securing a small boat along the drill path to support on-site swimmer/diver activities.

When tracking the drill assembly on land, the maximum range of the tracking system used is about 70 feet below the ground's surface. However, the range of this wireless system is reduced significantly when operating over seawater, due to the increased attenuation of the tracker's electro-magnetic signal in seawater.

On-site tests were conducted by suspending the beacon (normally mounted inside the drill head assembly) from a small boat, and monitoring its readings compared with its actual water depth. The maximum beacon range (i.e., depth) exhibited was 30 to 40 feet. When submerged 30 feet, the instrument would provide accurate inclination and orientation readings, but would give a depth reading of 60 feet.

Hence, accurate data on the orientation of the directional drill head was not available after the borehole extended out past the shoreline. Once the tracker was out of range, it was primarily the driller's experience and insight that kept the borehole on track. Also, the divers played a significant role by listening for the drill head, and estimating its depth and position beneath the seafloor. Lack of drill tracking ability offshore presented a significant problem during this effort, given the complex nature of the lava substrate formations being drilled.

The drilling rate achieved through the hard lava formations at this site averaged approximately 230 feet per day, for nominal 12-hour work days. During the course of drilling, drill mud usage averaged 13 gpm. During pullback operations, or when drilling through softer, less consolidated material, the mud usage was increased to 20 to 25 gpm. The mud mixture was varied throughout the course of drilling, to accommodate the changes in the material being drilled.

BOREHOLE LINER INSTALLATION

A liner (conduit) is required in boreholes to ensure that the holes stay open for cable coming ashore. Installation of the conduit in the boreholes was accomplished by pulling HDPE pipe back through each borehole upon the completion of drilling. The process involved divers first locating the drill pipe exiting the seafloor. The divers remove the drill head assembly with specialized tools, as shown in Figure 6. The divers then attach a pull back swivel to the drill pipe, as shown in Figure 7.

Figure 5. Drill-Tracking Receiver.

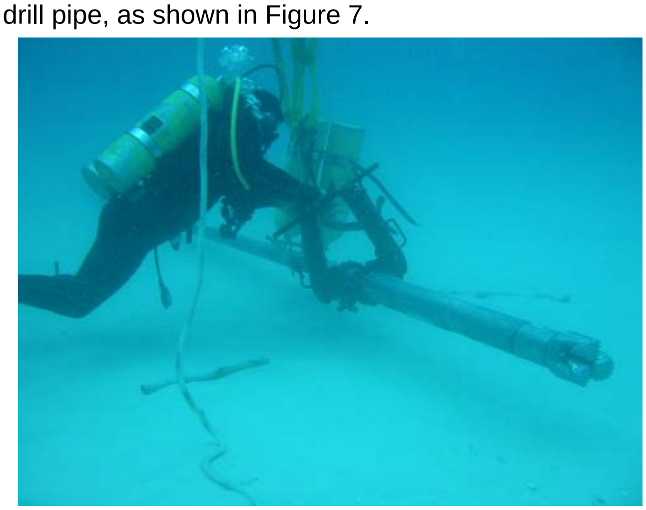

Figure 6. Diver Removing Drill Head.

Figure 7. Diver Installing Pull-Back Assembly.

At this point, the entire length of liner tubing is laid out on the shore, and a pulling tape installed for later hauling the cable. The tubing is then pulled offshore with a small boat (as shown in Figures 8 and 9). Divers then secure this tubing to the swivel assembly with a duct puller. Finally, the drill rig pulls the conduit back through the borehole with the drill pipe to complete the hole.

Figure 8. Deploying Borehole Liner Over Sand

Figure 9. Deploying Borehole Liner Over Rock.

OBSERVATIONS ON DRILLING OPERATIONS

Three subsurface conduits were ultimately installed at the site. The first borehole exited the seafloor in a rock outcropping, and was completed as an option for landing a possible electric grounding cable. The second borehole exited the seafloor among the rock outcroppings, but with a clear corridor of flat seafloor leading offshore. The third borehole exited the seafloor well beyond the rocky region. Figures 6 and 7 give an indication of the angle at which the boreholes exit the seafloor. These three boreholes are 470, 570, and 820 feet in length, and exit the seafloor at water depths between 35 and 45 feet. This effort took 13 days on site to accomplish.

The tendency during drilling was for the drill head to creep to the left and to rise up. Each subsequent drill plan added more depth and down angle to the borehole profile, to offset this phenomenon. In addition, more emphasis was placed on the diver's input as experience was gained in listening for the drilling noise. The increased lengths of the successive boreholes reflects the ever-increasing improvement gained by the drillers in understanding the formations at this particular site, and in overcoming the drill tracking limitations. Figure 10 shows the relative lengths of the three boreholes, and their positioning with respect to the site, overlain on a side-scan image of the seafloor.

Generally speaking, a driller would need at least 5 years of experience drilling in similar formations before being qualified to attempt a drill job such as this one. This experience would include planning borehole profiles as well as actually drilling them. In addition, such a driller would need as many years experience drilling under seawater. A driller must be able to recognize when seawater is intruding into the borehole, and breaking down the drill fluid.

Figure 10. Borehole Routes Overlaid on the Site Survey Data.

Many of the drilling tasks can be carried out by personnel with only rudimentary training. This includes handling the drill tracker, mixing the drilling fluid, and even operating the drill rig. Given their experience as heavy equipment operators, Navy divers were able to operate the drill rig (with some guidance; during the later part of the project). Also, a number of divers ran the drill tracker, and assisted with mud mixing duties. However, such duties can only be carried out when under the supervision of specialized drilling personnel.

Two experienced drillers are required on site to plan the boreholes, determine the optimum drill mud mixture, and operate the drill rig under difficult and/or changing conditions. Typically, the driller in charge operates the tracking instrument and gives direction to the drill rig operator. Given additional time on site for reduced productivity, one experienced driller could potentially run a job, if provided with competent operational support.

Drill fluid additives are available for carrying out drilling operations with seawater as the base for the drill fluid. These would pose additional operational hindrances, such as the requirement for 1/2 to 1/3 more clay additive than for fresh water.

SUMMARY

A shore landing cable protection system, comprised of subterranean boreholes, was successfully installed at Southwest Bay, Ascension Island, using a mobile, horizontal directional drilling system. These directionally drilled boreholes by-pass the surf zone, thus providing protection to future cables coming ashore. The boreholes range in length from 500 to 800 feet, and exit the seafloor in water depths of 35 feet or more.

Although the drilling was successful, lack of tracking ability when the drill head operated below seawater was a significant shortcoming of the drill system's capability experienced during this project. The use of seasoned drillers with experience drilling in this type of formation and at shore/sea interfaces was critical to the success of this project. Also instrumental was the divers' ability to estimate depth and position (beneath the seafloor) of the drill head, based on its generated noise.

As a result of this project, advances have since been made by the manufacturer in modifying the drill head tracking system for use in seawater.

ACKNOWLEDGMENTS

The participants in this successful operation included directional drillers from Ditch Witch Northwest and Island Mechanical Inc., Navy Underwater Construction Team One (UCT-1) divers, Sound & Sea Technology technical support, and MAR Inc. logistics support. In addition, outstanding shore support was provided by CSR personnel, the base operation and maintenance staff contracted by the Air Force.